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PROGRESS REPORT

FARS Cirrus Measurements for FIRE II

NASA Grant No. NAG-1-1314

17 July 1992 - 30 November 1994

Prepared by

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1. Introduction

In this report we summarize the middle portion of our cirrus cloud research effort in support of Project FIRE Phase II, covering the period from mid-July 1992 to November 1994. This cirrus cloud research program represents a continuation of Project FIRE studies begun during the October-November 1986 Intensive Field Observations (IFO) I campaign from Wausau, Wisconsin, the Extended Time Observations (ETO) component from the University of Utah Facility for Atmospheric Remote Sensing (FARS) at Salt Lake City (commencing in December 1986), and our participation in the IFO II experiment at the Hub site near Coffeyville, Kansas, during November-December 1991. The scope of our research program has recently been expanded through supplemental support from the SASS program to include increased ETO data collection and retrospective ETO data analyses of contrail-cirrus clouds. Recent research in the ETO and IFO components are summarized in the following two sections.

2. Extended Time Observations at FARS

a. FARS Instrumentation

FARS is located on the edge of the University of Utah campus at an elevation of 1.52 km MSL at $40^{\circ} 46' 00''$ N and $111^{\circ} 49' 38''$ E. The kernel of instrumentation at FARS used in cirrus cloud research includes a dual-polarization ruby lidar system, which provides uncalibrated backscatter and linear depolarization data, and a suite of roof-mounted visible and infrared radiometers. One of the passive instruments, a midinfrared narrowbeam radiometer, is coaligned with the lidar to obtain cirrus cloud infrared emittances

using the LIRAD technique. The specifications of these instruments are provided in Table 1, along with those of two new state-of-the-art remote sensors: the Polarization Diversity Lidar (Sassen 1994) and the 95 GHz polarimetric Doppler radar, which are being integrated into ETO studies on a selective case study basis. All lidar and radiometric data are routinely transferred to 8 mm Exabyte tape for data archival, and analysis on VAX workstations.

The ETO remote sensing data records are supplemented by case-by-case data files containing the twice-daily radiosonde profiles launched from the Salt Lake City National Weather Service station (12 km to the west of our field site), as well as stored data products available from our advanced synoptic laboratory, including satellite imagery and upper air charts. Data from a 5-beam 404.37 MHz wind profiling system located at Dugway Proving ~50 km to the west are also logged when available at our synoptic laboratory.

b. ETO DATA Collection

Compiled in Appendix 1 are the ETO Data Summary sheets inclusive of the period of performance of concern here (Report Nos. 27-35), and in Table A1, an explanation sheet for the various column entries. Note that the ETO-supporting listings are identified by asterisks in the Date column (i.e., for days 5-10 and 20-25 of each month). Other listings show cirrus cloud data collection on non-primary days, which were funded by the National Science Foundation, but which will be made available to FIRE researchers and included in our climatological cirrus research component. The observation sets are typically collected for 1-3h

Table 1. University of Utah Facility for Atmospheric Remote Sensing (FARS) Research Capabilities

1. Passive Remote Sensors

- a. Net Flux Pyrradiometers
- b. Narrow-beam (0.14°) $9.5\text{-}11.5\mu\text{m}$ radiometer (co-aligned with lidar)
- c. Precision Infrared Radiometer
- d. Pyranometer, $0.3\text{-}2.8\mu\text{m}$ broadband visible
- e. Rotating Shadowband Radiometer ($0.63\text{-}2.5\mu\text{m}$)
- f. Pyrheliometer ($0.63\text{-}2.8\mu\text{m}$) with solar tracker
- g. All-sky 35mm photography
- h. All-sky video time-lapse imagery

2. Active Remote Sensors

- a. Polarization Cloud Lidar (PCL)
 - Two channels
 - Vertical polarization transmitted
 - Manually "tiltable" $\pm 5^\circ$ from zenith
 - 10 s PRF, 7.5 m maximum range resolution
 - Maximum 2K per channel data record length
 - 1-3 mrad receiver beamwidths
 - 25 cm diameter telescope
 - $0.694\mu\text{m}$ wavelength, 1.5 J maximum output
- b. Two-color Polarization Diversity Lidar (PDL)
 - Four channels
 - Vertical ($0.532\mu\text{m}$) + horizontal ($1.06\mu\text{m}$) polarizations
 - Fully scannable, 5°s^{-1}
 - 10 Hz PRF, 1.5 m maximum range resolution
 - 2-8K per channel data record length
 - 0.23-3.8 mrad variable beamwidths
 - 35 cm diameter telescopes (two)
 - Simultaneous 0.532 and $1.06\mu\text{m}$ wavelengths, 0.45 J outputs
- c. 95 GHz Polarimetric Doppler Radar
 - Six channels (two Doppler)
 - Vertical + horizontal polarizations transmitted
 - Vertically pointing*
 - 10Hz-80KHz PRF, 7.5 m maximum range resolution
 - 100-600 range gates
 - 0.25° beamwidth
 - 90 cm diameter dish, 57 dB gain
 - 3.2 mm wavelength, 1.2 KW peak power

3. Meteorological Sensors

- a. Temperature
- b. Relative Humidity

*Scanning capabilities being added

periods bracketing the local overpass to obtain data on cirrus cloud structural variability, encompass consecutive overpasses, and make allowances for inaccuracies in the predicted ephemeris. Figure 1 provides a summary of all ETO high cloud data collected at FARS up to September 1994 as part of our FIRE I and II research activities.

c. ETO Case Study Analyses

In keeping with our approach to identify especially important cirrus cloud properties for immediate examination (i.e., before the availability of the final climatological FIRE ETO dataset), we have recently published and reported at conferences new findings from our growing ETO dataset. In Sassen et al. (1994a), coincidental polarization lidar observations of the lower-stratospheric aerosols associated with Bishop's ring aureole displays have revealed the presence of nonspherical particles, which recent theory suggest may be composed of sulfuric acid tetrahydrate. An examination of the ETO frequencies of occurrence of various cirrus cloud optical displays aided in the analysis of possible prehistoric Indian rock art depictions of halos and arcs in the Great Basin (Sassen 1994b), a matter of some historical interest. We have also examined our photographic fisheye record of hourly ETO cirrus cloud images to determine the frequency of persisting contrails, and analysed some contrail case studies using lidar and midinfrared radiometer data to begin an assessment of the potential regional climatic effects of contrails, as reported in Sassen et al. (1994b) and Sassen (1995). Contrails generated from commercial jet traffic in major

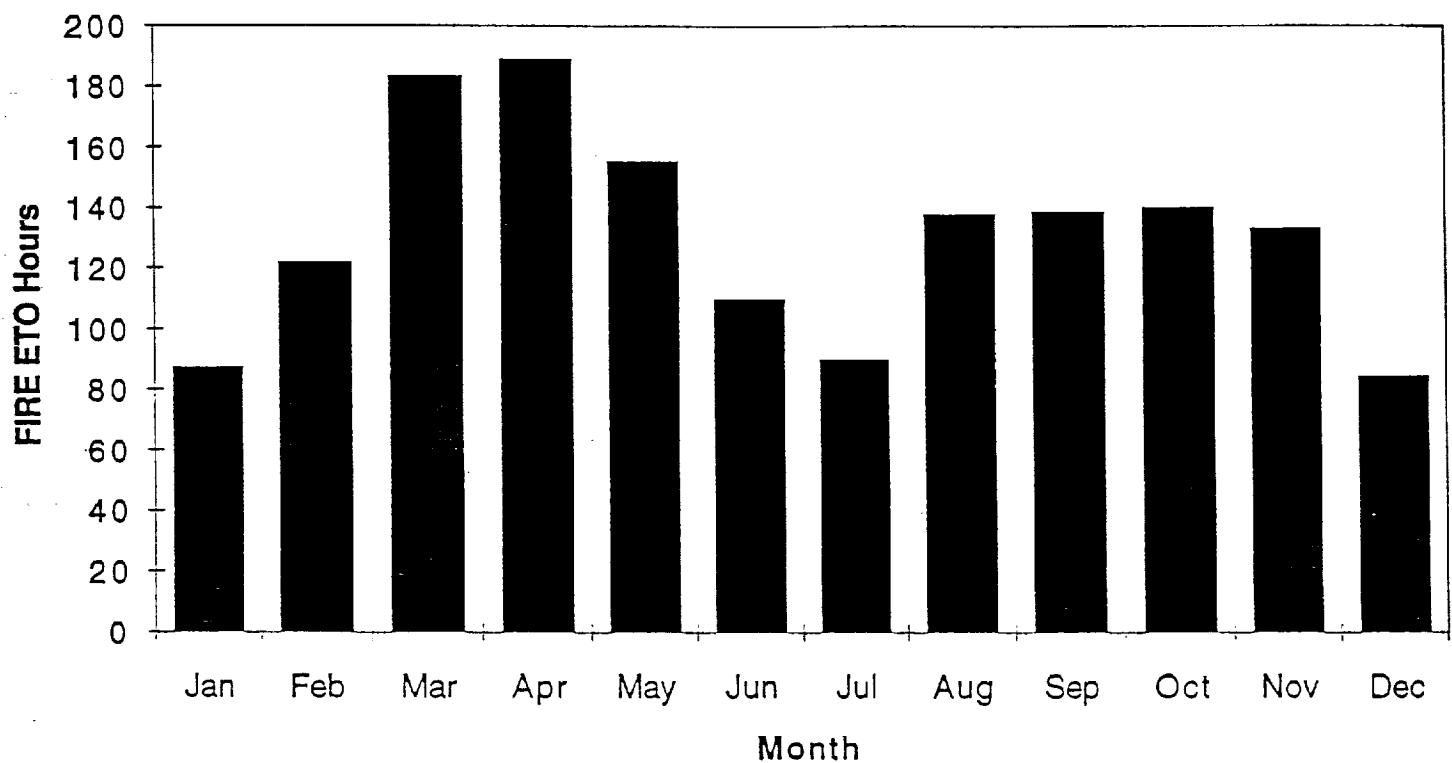


Figure 1. The monthly distribution of Project FIRE ETO hours collected since December 1986 at FARS, reflecting the seasonal variations in synoptic conditions associated with cirrus clouds that are observable from our site in Salt Lake City, UT.

local air corridors have been identified in ~20% of the fisheye images, and their visible and infrared optical effects have often been shown to be relatively significant. The temperature dependence of contrail persistence (derived from local rawinsondes) indicates that the homogeneous freezing of the droplets initially formed during the environmental mixing of jet engine exhausts are involved exclusively in generating contrails.

3. Intensive Field Observations at Coffeyville, Kansas

a. IFO II Instrumentation

The new University of Utah Polarization Diversity Lidar (PDL) system, developed from funding from the DOE Atmospheric Radiation Measurement program, was deployed during the 1991 Kansas Project FIRE IFO II field campaign at the Coffeyville Hub site. The specifications of this unit are listed in Table 1. Accompanying instrumentation included an all-sky video imaging system (data stored in timelapse on 8-mm video tape), the PRT-5-type infrared radiometer, and a zenith-pointing camcorder video camera.

b. IFO I and II Case Study Analyses

Having earlier identified a potentially important climatic affect caused by the indirect effects of the June 1991 Mt. Pinatubo eruptions on midlatitude cirrus clouds (Sassen 1992), we have now organized a comprehensive IFO II case study for 5-6 December 1991 using nearly the entire compliment of Hub instrumentation and supporting aircraft (Sassen et al. 1995). This work combines detailed synoptic analyses of jet streak-induced tropopause folds, in situ aircraft microphysical and aerosol data, and ground-based and NASA ER-2 lidar and radar findings of the aerosols and clouds

to make a strong case for the alteration of cirrus cloud properties resulting from the contamination of volcanic sulfate aerosols. The possible climatic effects of this phenomenon are also discussed.

Finally, an analysis of the largely-unexploited, impacted ice crystal photographic collection obtained aboard the NCAR King Air during the FIRE IFO I experiment has been used to investigate the actual structures of cirrus ice crystals, and assess the particle shape effects on halo generation in particular and radiative transfer in general (Sassen et al. 1994c). It was shown that the abundance of hollow and complex radial ice particles have important implications for cirrus cloud radiative models.

References

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- *Acknowledging NASA support.

APPENDIX 1

Table A1:
University of Utah ETO Data Summary Sheet Explanations

Lidar

Data Rate

- Regular (at maximum 10 s shot rate)
- Monitor (at less than the maximum PRF)
- Scan (elevation angle scanning operations)

Support Data

- Radiation
- Photographic (180° fisheye)
- IR Radiometer (narrow beam midinfrared radiance)
- Microwave Radar reflectivity data

Satellite

- NOAA 9, 10, 11, and 12 platforms

Cloud Conditions (± 15 min. of overpass)

Amounts of high, middle, and low cloud cover, where

- 1 = Overcast (10/10 coverage)
- 2 = Broken (6/10 to 9/10 coverage)
- 3 = Scattered (1/10 to 5/10 coverage)

Types - High

- 1 = Cirrostratus (uniform-appearing)
- 2 = Fibratus (fibrous, streaks, contrails)
- 3 = Spissatus (dense patches, anvils, lenticular)
- 4 = Thin or subvisual cirrus
- 5 = Thick, probably attenuation-limited
- 6 = Ice crystal optical phenomena (haloes, etc.)

Types - Middle

- 7 = ALSt (primarily ice phase)
- 8 = ALCu (cellular or lenticular, water phase dominates)

Types - Low

- 9 = Stratus, fog
- 10 = Cumulus, fractus
- 11 = Cumulus with significant vertical development, Cb
- 12 = Precipitation at site

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 14 Aug. - 13 Oct. 1992 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
 Elevation 1.52 km MSL

Date	Times (GMT)	Lidar										Satellite						Cloud Conditions							
		Data Rate	Sup- porting	Over- pass		E S		N R A N N	Time (GMT)	High		Mid.			Low			A	7	8	A	9	10	11	12
				N	1	B	G	1	1	A	1	2	3	4	5	6	A	7	8	A	9	10	11	12	
8/14	0233-0415	X		X	X	X			0244	X		2	X	X		3	X								
* 8/25	0030-0229	X		X	X	X			0338			X?	X	X		?	X								
8/27	2138-2200	X		X	X				0125			X 1	X X												
8/28	2139-2359	X		X	X				0141	X		1	X X												
8/29	0001-0030	X		X	X	X																			
	0125-0630	X		X	X	X			0140	X		1	X X												
		X		X	X	X			0146			X 1	X X												
		X		X	X	X			0320			X ?	X X												
9/1	1950-2359	X		X	X	X			2055			X 1	X X										3	X	X
9/2	0001-0018	X		X	X	X						2	X X										3	X	X
9/3	0118-0348	X		X	X	X			0125	X		2	X X	X											
		X		X	X	X			0130			X 2	X X	X											
		X		X	X	X			0310			X 2	X X	X											
* 9/8	1732-2119	X		X	X	X			2112			X 2	X X										?	(Smoke)	
* 9/10	0150-0413	X		X	X	X			0158	X		3	X	X											
		X		X	X	X			0221			X ?	X X												
9/14	1949-2145	X		X	X	X			2140			X ?	X										?	(Smoke)	
9/15	2042-2328	X		X	X	X			2126			X 1	X X	X									3	X	
		X		X	X	X			2307			X 1	X X	X									3	X	
9/19	1857-2310	X		X	X	X			2218			X 1	X X												
* 9/21	0046-0146	X		X	X	X			0055	X		2	X X												
		X		X	X	X			0145			X 3	X X												
* 9/23	2249-2336	X		X	X	X			2311			X 3	X X										3	X	X
10/2	1524-1610	X		X	X	X			1528	X		3	X										3	X	
10/4	0028-0148	X		X	X	X			0045	X		2	X X	X									3	X	X
* 10/5	1951-2150	X		X	X	X						2	X X												
* 10/6	0257-0510	X		X	X	X			0306			X 1	X X												
* 10/10	2121-2359	X		X	X	X			2128			X 2	X X X												
		X		X	X	X			2308			X 1	X X X												
10/11	0001-0134	X		X	X	X			0118	X		1	X X X												
		X		X	X	X			0120			X 1	X X X												
10/12	0051-0250	X		X	X	X			0054	X		1	X X X												
		X		X	X	X			0234	X		? X	X X X												
		X		X	X	X			0238			X ?	X X X												
10/13	0121-0244	X		X	X	X			0210	X		? X	X X												
		X		X	X	X			0217			X ?	X X												
	2040-2336	X		X	X	X			2232			X 1	X X												

*Primary satellite day.

Report No. 28

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 15 Oct. - 28 Dec. 1992 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar					Satellite						Cloud Conditions											
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.					Low										
				Time	(GMT)	N 1	B G		A 1	2	3	4	5	6	A 7	8	A 9	10	11	12				
10/15	0006-0314	X	X X	0122					X						X	X X X								
		X	X X	0135											X	? X X X X								
	1449-1749	X	X X X	1518				X							X	1 X								
		X	X X X	1532											X	1 X								
10/17	0120-0305	X	X X	0214				X							X	? X X								
		X	X X	0232											X	? X X								
	2130-2241	X	X X X	2144											X	1 X X								
*10/20	0040-0250	X	X X	0103				X							X	? X X								
		X	X X	0128											X	? X X								
		X	X X	0243				X							X	? X X								
11/4	2106-2209	X	X X X	2128											X	1 X							X	1 X
*11/6	0343-0558	X	X X	0347											X	? X								
11/17	2100-2352	X	X X X	2212											X	1 X							X	1 X X
11/19	1835-2030	X	X X X												X	1 X							2	X
*11/21	2213-2359	X	X X X	2305											X	1 X X							3	X
*11/22	0002-0340	X	X X	0113				X							X	1 X X								
		X	X X	0124											X	1 X X								
		X	X X	0253				X							X	? X X								
		X	X X	0304											X	? X X	X						?	X
11/27	2032-2310	X	X X X	2153											X	1 X X							3	X 3
12/1	2100-2330	X	X X X	2245											X	1 X							2	X
*12/7	0044-0314	X	X X	0154				X							X	1 X X								
		X	X X	0245											X	? X X	X							
*12/8	2150-2337	X	X X X	2302											X	1 X	X						3	X 3
*12/10	1830-2310	X	X X X	2237											X	1 X								
12/14	1748-2205	X	X X X	2149											X	1 X							X	3 X 3
12/17	0151-0317	X	X X	0232											X	? X X	X							
*12/21	2111-2230	X	X X X	2206											X	2 X X	X						3	X
12/27	0204-0334	X	X X	0217				X							X	? X X								
		X	X X	0219											X	? X X	X							
		X	X X X	2234											X	1 X								
12/28	0001-0220	X	X X	0153				X							X	1 X X								
		X	X X	0158											X	1 X X								

*Primary satellite day.

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UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: January - 13 March 1993 SITE: Lat. $40^{\circ} 46' 00''$ Long. $111^{\circ} 49' 38''$
 Elevation 1.52 km MSL

Date	Times (GMT)	Lidar					Satellite						Cloud Conditions					
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.	Low								
				Time	N 1 B G 1 1	9 0 S E 1 2	A 1 2 3 4 5 6			A 7 8	A 9 10 11 12							
Date	Times (GMT)	R	M	S	F	R	P	I	M									
* 1/5	2016-2359	X				X	X	X		2227		X	1 X					
* 1/6	0020-0213	X				X		X		0138	X		1 X		X			
						X		X		0206		X	1 X		X			
1/12	2232-2359	X				X	X	X		2240		X	1 X X	X	X			
						X		X		2345		X	1 X X					
1/13	0001-0232	X				X		X		0028	X		1 X X					
						X		X		0208	X		1 X					
1/15	2233-2359	X				X	X	X		2344		X	1 X X	X	3	X	3	X
1/16	0009-0058	X				X		X		0056	X							1 X
* 1/20	1820-2130	X				X	X	X					1 X		X	3	X	
	2221-2310	X				X	X	X		2244		X						1 X X
* 1/22	0009-0310	X				X		X		0121		X	1 X X	X				
						X		X		0153	X		? X					X
						X		X		0301		X	?					X
* 1/24	0040-0230	X				X		X		0105	X		1 X X		2	X		
						X		X		0218		X	?					X
2/19	1846-1937	X				X	X	X					3	X	X	2	X	3 X
	2151-2219	X				X	X	X								2	X	3 X
2/26	1427-1830	X				X	X	X		1430		X	1 X					
						X		X		1512	X		1 X					X
						X		X		1610		X	1 X					
	2332-2359	X				X	X	X		2340		X	1 X					
2/27	0001-0240	X				X	X	X		0052	X		1 X					
						X		X		0152		X	1 X					
						X		X		0232	X		?	X				X
	2210-2230	X				X	X	X					3	X				
2/28	0134-0314	X				X		X		0130		X	2	X X				
						X		X		0208	X		2	X X				
						X		X		0310		X	?	X				X
* 3/6	0111-0546	X				X	X	X		0125	X		1 X X	X		3	X	
						X		X		0242		X	?	X				X
* 3/7	2117-2359	X				X	X	X		2152		X	1 X X	X				
						X		X		2332		X	1 X X	X				
* 3/8	0001-0047	X				X	X	X		0037	X		1 X X	X				
	2216-2337	X				X	X	X		2320		X	1 X X					
* 3/10	0020-0152	X				X		X		0129	X		1 X X X					
3/12	2116-2359	X				X	X	X		2232		X	1 X					
3/13	0001-0030	X				X		X					1 X					

*Primary satellite day.

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Report No. 30

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 20 March - 16 May 1993 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
 Elevation 1.52 km MSL

Date	Times (GMT)	Lidar						Satellite						Cloud Conditions																		
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.	Low	N R A N N		Time		N 1 B G 1 1	(GMT)		9 0 S E 1 2	A 1 2 3 4 5 6	A 7 8	A 9 10 11 12											
				R	M	S	F				9	0	S	E	1	2	A	1	2	3	4	5	6	A	7	8	A	9	10	11	12	
* 3/20	0047-0415	X		X	X	X		0050	X									1	X	X	X					3	X					
		X		X	X	X		0230	X									1	X	X	X											
	2011-2335	X		X	X	X		0243										X	1	X	X											
* 3/24	1432-1737	X		X	X	X		1450	X										1	X	X	X										
		X		X	X	X		1515										X	1	X	X											
* 3/25	2104-2332	X		X	X	X		2136										X	1	X						3	X	3	X			
		X		X	X	X		2316									X															
3/26	2140-2335	X		X	X	X		2304									X	1	X	X	X	X			3	X	2	X	X			
3/27	0228-0340	X		X	X	X		0334									X	? X														
3/31	2010-2359	X		X	X	X		2204									X	1	X	X						3	X					
		X		X	X	X		2344									X	1	X	X												
4/1	0001-0035	X		X	X	X													1	X	X											
4/3	1843-2343	X		X	X	X		2123									X	1	X													
		X		X	X	X		2304									X	1	X													
4/4	0231-0430	X		X	X	X													1	X	X	X										
* 4/8	1950-2350	X		X	X	X		2203									X	1	X	X	X	X										
		X		X	X	X		2344									X	1	X													
* 4/9	0127-0325	X		X	X	X		0212									X	1	X													
		X		X	X	X		0243									X	1	X													
4/16	2238-2359	X		X	X	X		2348									X	1	X	X	X											
4/17	0001-0238	X		X	X	X		0115	X									1	X	X	X					3	X					
		X		X	X	X		0241									X	1	X	X	X											
	1740-2216	X		X	X	X		2155									X	1	X	X												
* 4/20	0153-0418	X		X	X	X		0317									X	3	X													
	1855-2255	X		X	X	X		2259									X	1	X													
* 4/21	2143-2313	X		X	X	X		2247									X	1	X									1	X			
* 4/22	0209-0320	X		X	X	X		0234									X	1	X	X	X					3	X					
		X		X	X	X		0236	X									1	X	X	X					3	X					
* 4/23	2018-2336	X		X	X	X		2223									X	1	X	X	X					3	X					
* 4/25	2130-2359	X		X	X	X		2158									X	1	X	X	X											
		X		X	X	X		2339									X	1	X	X												
4/28	2146-2318	X		X	X	X		2303									X	1	X	X	X											
5/13	0022-0244	X		X	X	X		0053	X									2	X													
		X		X	X	X		0145									X	2	X	X												
		X		X	X	X		0233	X									1	X													
5/14	0239-0339	X		X	X	X		0303									X	1	X													
5/16	0050-0350	X		X	X	X		0121	X									1	X	X												
		X		X	X	X		0220									X	1	X	X												

*Primary satellite day.

Report No. 31

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 18 May - 30 Nov 1993 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar										Satellite						Cloud Conditions											
		Data Rate	Sup- porting	Over- pass		E S				High		Mid.			Low														
				N	R	A	R	N	D	A	1	2	3	4	5	6	A	7	8	A	9	10	11	12					
5/18	0123-0327	X	X X X	0138				X	1	X X																			
		X	X X X	0213	X					1	X X																		
	2151-2359	X	X X X	0318				X	2	X																			
5/19	0001-0050	X	X X X	2221				X	1	X X	X																		
	2343-2359	X	X X X	2350				X	1	X X X X X												3	X						
*5/20	0001-0243	X	X X X	0126	X					1	X X	X																	
	X	X X X	0235					X	1	X X																			
*5/24	2320-2359	X	X X X								1	X X										3	X						
*5/25	0001-0240	X	X X X	0106	X					1	X X X	X										3	X X						
	X	X X X	0228					X	1	X X	X										3	X							
	2150-2359	X	X X X	2237				X	1	X X																			
5/26	1735-1910	X	X X X							1	X																		
	2140-2310	X	X X X	2225				X	2	X X																			
5/30	2212-2359	X	X X X	2317				X	1	X X X	X																		
5/31	0001-0040	X	X X X	0023	X				1	X	X	X																	
6/1	2223-2320	X	X X X	2253				X	2	X X	X											3	X						
*6/9	2250-2340	X	X X X	2257				X	2	X X X	X	X																	
*6/10	0001-0200	X	X X X	0123	X				2	X X	X																		
	X	X X X	0146					X	2	X X	X	X																	
	2103-2312	X	X X X	2244				X	1	X											2	X							
6/26	2242-2359	X	X X X	2252				X	2	X X	X																		
6/27	0001-0140	X	X X X	0116	X				2	X X																			
*7/21	1651-1746	X	X X X						2	X X												3	X						
	1940-2040	X	X X X							2	X X											3	X X						
7/30	0330-0510	X	X X							1	X X											3	X						
8/2	2033-2359	X	X X X	2200				X	2	X X																			
	X	X X X	2340					X	2	X X																			
8/3	0001-0030	X	X X X							2	X X																		
*8/5	2318-2353	X	X X X	2304				X	1	X X												3	X X						
*11/7	0901-0934	X	X							?	X X																		
*11/8	1808-2031	X	X X X							2	X X																		
*11/9	2320-2359	X	X X X	2339				X	1	X X X	X																		
	X	X X X	2357					X	1	X X X	X																		
*11/10	0004-0220	X	X X	0007	X				1	X X X	X																		
	X	X X	0146					X	1	X X X	X																		
	X	X X	0155						1	X X X	X																		
*11/21	2129-2229	X	X X X							1	X X X	X										3	X X						
11/29	2238-2359	X	X X X	2257				X	1	X X X	X																		
11/30	0001-0138	X	X X	0027	X				1	X X X X X	X																		
	X	X X	0126					X	1	X X X X X	X																		

*Primary satellite day.

Report No. 32

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 1 Dec. 1993-20 Feb. 1994 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar						Satellite						Cloud Conditions															
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.	Low																			
				Time	N 1	N	R A N N				9 0 S E 1 2	A 1	2	3	4	5	6	A 7	8	A 9	10	11	12						
12/1	2315-2359	X		X X X								1	X X					3	X										
12/2	0001-0243	X		X X X	0013			X	1	X X	X	3	X																
		X		X X	0119	X			?	X X	X																		
		X		X X	0223				X	?	X	X						?	X										
*12/10	0751-1110	X		X X								1	X X X																
12/11	2154-2359	X		X X X	2211			X	1	X X	X	3	X																
		X		X X X	2352			X	1	X X X	X	3	X	3	X														
12/13	2241-2359	X		X X X	2327			X	1	X X	X	3	X																
12/14	0001-0040	X		X X	0015	X			1	X X		3	X																
	1953-2328	X		X X X	2315			X	1	X X	X	3	X X																
12/19	0030-0130	X		X X	0111	X			?	X	X																		
		X		X X	0118				X	?	X	X																	
*12/25	2235-2359	X		X X X	2242			X	1	X X	X																		
12/26	0001-0032	X		X X X	0003	X			1	X X	X																		
		X		X X	0022			X	1	X X	X	X	X																
	1827-2120	X		X X X					1	X X																			
12/30	2246-2357	X		X X X	2319			X	1	X																			
1/2	2024-2335	X		X X X	2243			X	1	X X		3	X																
1/4	2042-2127	X		X X X					1	X		2	X X																
* 1/7	2238-2355	X		X X X	2322			X	1	X X	X																		
* 1/22	0546-0733	X		X X					?	X	X																		
* 1/24	2228-2359	X		X X X	2316			X	1	X X																			
* 1/25	0001-0140	X		X X	0050		X	1	X	X																			
		X		X X	0117			X	1	X	X																		
		X		X X	0120	X			1	X	X																		
1/28	2154-2254	X		X X X	2227			X	3	X	X																		
1/31	2314-2359	X		X X X	2331			X	1	X X		3	X 3	X															
2/1	0001-0032	X		X X X	0013	X			1	X	X	3	X																
2/4	2143-2359	X		X X X	2242			X	1	X X	X																		
* 2/5	0001-0040	X		X X X	0017	X			1	X X	X	3	X																
		X		X X X	0023			X	1	X X	X	3	X																
* 2/6	1754-2230	X		X X X	2218			X	1	X		X																	
2/13	2214-2359	X		X X X	2233			X	1	X	X																		
2/14	0001-0110	X		X X X	0001	X			1	X X																			
		X		X X X	0014		X		1	X X																			
2/15	2135-2359	X		X X X	2209			X	1	X X																			
2/16	0001-0205	X		X X X	0053	X			1	X X	X																		
* 2/20	0149-0412	X		X X	0144		X	1	X X	X																			
		X		X X	0158			X	1	X X	X																		

*Primary satellite day.

Report No. 33

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 23 Feb - 6 Aug 1994 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar						Satellite						Cloud Conditions																
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.						Low															
				Time	(GMT)	N	R	A	N	N	1	B	G	1	1	1	A	1	2	3	4	5	6	A	7	8	A	9	10	11
*2/23	1803-1908	X		X X X														1	X X	X										
	2318-2359	X		X X X		2350											X	3	X								3	X		
3/4	1741-2040	X		X X X														1	X X	X	X	X								
*3/10	1730-1940	X		X X	X													1	X											
3/13	2123-2359	X		X X		2332											X	1	X X	X										
3/14	0001-0040	X		X X		0024											X		1	X X	X									
	2106-2359	X		X X		2319											X	1	X X	X	X	X								
3/15	0001-0032	X		X X		0001											X		1	X X	X	X								
	2210-2359	X		X X		2307											X	1	X											
3/16	2222-2359	X		X X	X	2255											X											1	X	
*3/23	1814-1912	X		X X															3	X	X								3	X
3/29	1807-2050	X		X X															1	X X	X									
3/31	0022-0240	X		X X		0117											X	2	X X											
		X		X X		0156											X	1	X X	X										
*4/5	2344-2359	X		X X		2352											X	1	X X	X								3	X	
*4/6	0001-0212	X		X X		0111												1	X X	X								3	X	
5/27	2123-2305	X		X X														2	X X										3	X
5/31	0135-0305	X		X X X		0239											X	2	X X											
6/2	2313-2359	X		X X X		2344											X	1	X X	X										
6/3	0002-0320	X		X X X		0115											X	1	X X	X										
		X		X X X		0134											X	1	X X	X										
		X		X X		0314											X	1	X X	X										
6/4	0043-0306	X		X X X		0051											X	1	X											
		X		X X X		0113											X	1	X											
		X		X X X		0253											X	1	X	X								3	X	
6/12	0146-0335	X		X X		0321											X	1	X X											
	1838-2234	X		X X X														1	X X									3	X	
*6/23	2136-2208	X		X X X														3	X X											
*6/24	1854-2128	X		X X X														1	X X											
6/27	2104-2246	X		X X X														1	X X											
*7/7	1954-2102	X		X X X																									3	X
7/16	0152-0308	X		X X X		0244											X	1	X X									3	X	
7/17	1833-0308	X		X X X														2	X X										3	X
	2225-2359	X		X X X		2253											X	1	X X										3	X
		X		X X X		2351											1	X X										3	X	
7/18	0001-0140	X		X X X		0034											X	1	X X									3	X	
		X		X X X		0131											1	X X										3	X	
	2113-2129	X		X X X														3	X											
*8/6	2338-2359	X		X X X		2349											X	2	X X											

*Primary satellite day.

Report No. 34

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 7 Aug. - 11 Sept. 1994 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar										Satellite						Cloud Conditions												
		Data Rate	Sup- porting	Over- pass		E S				High		Mid.			Low															
				N	R	A	N	Time	N	1	B	G	1	A	1	2	3	4	5	6	A	7	8	A	9	10	11	12		
*8/7	0001-0235	X		X	X	X		0010	X		2		X																	
		X		X	X	X		0130			X	1		X																
		X		X	X	X		0150	X		1		X	X																
*8/8	0129-0340	X		X	X	X		0126	X		1	X	X		X	1	X	X	X		3	X	3	X						
		X		X	X	X		0248			X	1	X	X	X	3	X				3	X								
*8/9	2244-2349	X		X	X	X		2313			X	1		X	X											3	X	X		
*8/10	2141-2310	X		X	X	X		2300			X	1		X	X											3	X	X		
8/12	0016-0135	X		X	X	X		0029			X	2	X	X	X							3	X							
		X		X	X	X		0122			X	3	X									3	X							
		X		X	X	X		0129	X		3	X										3	X							
	2333-2359	X		X	X	X						2	X										3	X	X					
8/13	0001-0130	X		X	X	X		0016			X	1	X	X	X	X	3	X	3	X	X									
		X		X	X	X		0105	X		2	X	X								3	X	3	X	X					
	2240-2359	X		X	X	X						2	X	X									3	X	X					
8/14	0001-0103	X		X	X	X		0004			X	3	X	X								3	X	X						
		X		X	X	X		0041	X		3	X	X									3	X	X						
8/18	0202-0502	X		X	X	X		0233			X	1	X	X	X															
	1351-1538	X		X	X	X		1441	X		2	X	X									3	X							
		X		X	X	X		1450			X	2	X	X								3	X							
*8/20	2038-2351	X		X	X	X		2239			X	2	X	X									3	X	X					
8/26	0838-1149	X		X	X			1139			X	?	X	X																
8/31	0237-0407	X		X	X			0249			X	3	X										3	X						
9/2	1542-1722	X		X	X	X		1602			X	2	X	X									3	X						
9/3	0019-0153	X		X	X	X		0059	X			2	X	X																
		X		X	X	X		0059			X	2	X	X																
		X		X	X	X		0144			X	3	X										3	X	3	X				
9/4	0034-0134	X		X	X	X		0035	X		0																			
		X		X	X	X		0047			X	0																		
		X		X	X	X		0123			X	0																		
*9/6	2055-2115	X		X	X	X						3		X																
*9/8	1846-2048	X		X	X	X						1	X	X																
*9/9	2246-2359	X		X	X	X		2333			X	1	X	X																
		X		X	X	X		2351	X		1	X	X																	
*9/10	0001-0433	X		X	X	X		0131	X			1	X	X	X															
		X		X	X	X		0233			X	1	X	X																
9/11	0719-0810	X		X	X			0747	L														3	X						
	0900-0920	X		X	X			0915	L														?	X						
	2256-2359	X		X	X	X		2308			X												3	X						
		X		X	X	X		2348	L														3	X						

*Primary satellite day.

Report No. 35

UNIVERSITY OF UTAH LIDAR ETO DATA SUMMARY

PERIOD: 12 Sept. - 29 Oct. 1994 SITE: Lat. 40° 46' 00" Long. 111° 49' 38"
Elevation 1.52 km MSL

Date	Times (GMT)	Lidar							Satellite						Cloud Conditions													
		Data Rate	Sup- porting	Over- pass		E S		High	Mid.	Cloud Conditions		Low																
				N	R	N	S	E	1	B	G	1	A	1	2	3	4	5	6	A	7	8	A	9	10	11	12	
9/12	1842-1935	X		X	X	X									1	X	X	X					2	X	X			
	2320-2359	X		X	X	X									2	X	X						3	X				
9/13	0001-0107	X		X	X	X	0019	X							2	X	X						3	X				
		X		X	X	X	0037			X					2	X	X						3	X				
	0706-0747	X		X	X	X	0731		L														?	X				
	2309-2359	X		X	X	X	2338	L			3	X	X									2	X	X				
		X		X	X	X	2355	X		?												2	X	X				
9/14	0701-0752	X		X	X	X	0727	L														?	X					
9/16	0704-0745	X		X	X	X	0715	L		0																		
	2337-2359	X		X	X	X	2347				X	3			X							3	X	X				
9/17	0001-0147	X		X	X	X	0023	X			3	X	X	X								3	X	X				
		X		X	X	X	0142			X	3	X	X									3	X	X				
9/18	0542-0810	X		X	X	X	0656	L			?	X	X									?	X					
9/19	0142-0340	X		X	X	X	0239				X	1	X	X	X							3	X					
* 9/24	2244-2359	X		X	X	X	2350			X	1	X	X	X														
* 9/25	0020-0130	X		X	X	X	0054	X			2	X	X	X														
10/4	2302-2359	X		X	X	X	2327			X	1	X	X								3	X	3	X				
		X		X	X	X	2350	X			1	X	X		X	3	X	3	X									
*10/5	0001-0210	X		X	X	X	0108			X	1	X	X								3	X	3	X				
		X		X	X	X	0130	X			1	X	X		X	3	X	3	X									
		X		X	X	X	0154			X	1	X			X	?	X	?	?									
10/11	2023-2212	X		X	X	X									1	X	X					3	X	3	X			
10/12	1430-1713	X		X	X	X	1455			X	1	X	X	X								3	X					
	1813-1911	X		X	X	X									1	X	X	X				3	X					
	2304-2359	X		X	X	X	2329			X	1	X	X	X							3	X						
		X		X	X	X	2354	X			1	X	X	X														
10/13	0001-0050	X		X	X	X						1										2	X					
*10/20	2233-2359	X		X	X	X	2331			X	2	X	X	X								3	X					
*10/21	0001-0015	X		X	X	X	0002	X			2	X	X	X								3	X					
*10/23	1521-1558	X		X	X	X	1557			X	3	X																
10/26	1847-2020	X		X	X	X									1	X						3	X					
		X		X	X	X	2358			X	1	X			X	2	X											
10/27	0001-0111	X		X	X	X	0057	X			1	X			X	2	X											
		X		X	X	X	2345			X	1	X	X	X														
10/28	0001-0215	X		X	X	X	0033	X							1	X	X	X										
		X		X	X	X	0152								X	?	X	X	X									
10/29	0001-0152	X		X	X	X	0009	X							1	X	X					2	X					
		X		X	X	X	0114			X	1	X	X								2	X						
		X		X	X	X	0130			X	?	X	X								?	X						
		X		X	X	X	0149			?	X	X									?	X						

*Primary satellite day.